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GUIDELINES FOR RESIDENTIAL SOURCE CHARACTERIZATION PROGRAM

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Two recent residential magnetic-field surveys designed to test the accuracy of surrogate wiring-code estimates in ranking homes are analyzed, and the results are used to suggest guidelines for the Source Characterization program.

INTRODUCTION

Two epidemiological studies carried out in the Denver area have raised the hypothesis that increased levels of power-frequency magnetic fields in residences may be associated with increased incidences of childhood cancer. This hypothesis is based on the use of a surrogate method of estimating the historical level of residential magnetic field, using the physical characteristics of the nearby distribution wiring rather than actual magnetic field measurements.

While some relationship between the magnetic fields in a house and the currents in nearby wires will clearly exist, the actual extent to which particular internal or external conductors will contribute to the residential environment, and by what mechanism, is not well understood. Until this information is available, the validity of the surrogate method is questionable and the above hypothesis must remain untested, at least in the short term.

The Magnetic Field Source Characterization Program, presently being developed by the Research Division as part of a Corporate EMF risk assessment program, is designed to provide information about the detailed mechanisms by which magnetic fields are produced in homes. In order to assist in the development of this program, two recent surveys of residential magnetic fields, one in the Denver area and the other in the Tacoma/Seattle/Everett area of the United States, are analyzed, and the results are used to suggest guidelines for the program.

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THE RESIDENTIAL SURVEYS

The first survey was reported by Barnes, Wachtel, Savitz and Fuller/1/, and was undertaken to test the validity of the surrogate method, known as the Wertheimer-Leeper code after its originators, that was used in the Denver epidemiology studies. One-time (or spot) magnetic field measurements were made in 434 residences that were also classified according to the W-L code and it was concluded that the code was "a useful method for making a first-order approximation to predicting the long-term, low-level magnetic fields".

The second survey was reported by Kaune, Stevens, et al/2/ and had basically the same objective in relation to a Washington State epidemiology study. Only 43 homes were surveyed but the measurements were much more detailed, including both 24-hour time averaged measurements at three different locations in the home and independent spot measurements. An evaluation of harmonic content was also made. A modest correlation coefficient of 0.41 with the W-L code was found and a revised 3-variable code was proposed that significantly raised the correlation coefficient to 0.72.

It is not the purpose of this report to discuss the above surveys in detail, but rather to extract from them any information that may be relevant to the source characterization program with particular reference to relationships within individual residences.

AVERAGE MAGNETIC FIELDS

Residential magnetic fields are given in both studies as a function of the W-L wiring code. This code essentially divides the homes into four groups that may be described as very low, ordinary low, ordinary high, and very high current configurations (VLCC, OLCC, OHCC, and VHCC).

In the Denver spot measurements, mean fields ranged from about 0.05 μT for VLCC homes to 0.21 μT for VHCC homes under conditions of minimal residential power consumption and were 30 to 50% higher with heavy power consumption. Individual measurements are not given but the standard deviations are approximately the same size as the means, suggesting a large amount of scatter in the data.

Individual 24-hour average measurements are given for the Washington State study in a scatter plot (Figure 8 of the paper) from which code-group averages may be estimated. The individual 24-hour averages range from about 0.003 to 0.55 μT, with the latter value in an OLCC home, and the group averages are very similar to the results of the Denver study. A daily cycle is observed in the 24-hour period that averages out over all residences to about a 2:1 variation. However, the size of the variation in individual residences is not explicitly given.

SPOT VS TIME-AVERAGE MEASUREMENTS

Spot and 24-hour averaged measurements were found in the Washington State study to have a correlation coefficient of 0.51 but the scatter was fairly large, the spot measurements ranging from 20 times lower to 4 times higher than the average for individual homes. This is a range of 80:1 relative to the 24-hour average and another factor of two may be needed to account for seasonal variations, according to the authors of the Denver study.

EFFECT OF HARMONICS

Measurements made with a detector output linearly proportional to frequency showed that the measured fields were increased by factors up to 70%, with a mean increase of about 20%, in comparison with measurements made with a flat detector response. This increase is attributed to harmonics in the magnetic field waveform. Induced currents will scale with the linear measurements rather than the flat response.

EFFECT OF LOCATION

The three time-averaging probes used in the Washington State study were placed respectively in the family room near potential field-producing appliances, in the family room farther away from these sources, and in the bedroom. The overall-average fields recorded at these locations were all essentially the same (0.1 μT) and they were therefore all grouped together in the analysis. However, the fields were not necessarily well correlated in individual homes. This would suggest that, for diagnostic purposes, the placement of probes and the information recorded by them need to be selected with some care. Although stray ground currents are proposed in both surveys as important sources of magnetic field, there is no indication in the available material that any measurements were made with specific reference to the location of the neutral and ground return loop/3/. Therefore the effect of this loop cannot be inferred from the data.

EFFECT OF ELECTRICAL CONSUMPTION

In the Washington State study, no correlation was found between the consumption of electrical energy in the home and the measured fields, whereas in the Denver study, the fields increased with greater electricity usage. These apparently differing conclusions probably result from different methods of analysis rather than real differences in the two survey areas. In practical terms, consumption-related fields are most likely to be produced by an unbalanced current in the ground return/3/. In this event, the fields will depend more on the use of a single appliance such as a hair dryer, than they will on the overall electrical consumption and statistical averages may not show an effect. This question can therefore be resolved in individual houses only by measuring ground and neutral currents rather than electrical consumption.

EFFECTS OF EXTERNAL WIRING

Although its use would be questionable for individual residences, the 3-variable code proposed by the authors of the Washington State study was found in that study to yield a statistical correlation coefficient of 0.72 and may provide some insight into the relative effects of external wiring. Briefly summarized and simplified for purposes of illustration, this code is given by the following formula:

$$B = \sqrt{K^2 + (2L/r^2)^2 + (Mp)^2 + (P(d-1)^2)^2}$$

where B is the magnetic field and K, L, M, and P are adjustable parameters. The variable r is the horizontal distance to a transmission line, p is the number of primary phases on the distribution line(s), and d is the number of secondary service drops, all within 43 m of the house. The best fit parameters for the Washington State data are:

$K = 0.055\ \mu T$ $\quad$ $M = 0.030\ \mu T$
$L = 24.8\ \mu T.m^2$ $\quad$ $P = 0.002\ \mu T.$

As an example, a "baseline" house with no transmission line or primary distribution line and one secondary service drop will have a calculated field of 0.055 μT. This is a VLCC or "endpole" home according to the W-L code. The effect of adding a 3-phase primary distribution line and 6 secondary service drops, representing a common urban situation, raises the field to 0.117 μT and the house to a classification somewhere between OLCC and OHCC in the W-L code. These values and the further effect of adding a transmission line at a horizontal distance of 35 meters from each of the above houses, are shown in Table I.

It is interesting to note that the effect of locating a transmission line 35 m from the house is to increase the calculated average field by about 25% for the baseline house and by only 5% for the representative urban house. The small effect of the transmission line in comparison with the distribution primary and the secondary drops, may be due to a much lower coupling between the remotely grounded transmission line and local residential ground loops. However, these values are based on a sample of only two houses, and the predictive uncertainties will consequently be rather large.

TABLE I

Calculated fields based on modified code (in μT)

	baseline house	urban house
baseline field	0.055	0.055
with specified service drops added	0.055	0.074
with specified primaries added	0.055	0.117
with transmission line added	0.068	0.123

CONFOUNDING FACTORS

When measuring for certain effects, the possibility of confounding factors needs to be considered. Two such factors associated with the proximity of power lines might be electrochemical action associated with currents in the water pipes, and electric fields.

Electric fields were also measured in the two studies noted above. The fields were found generally to be in the range from 5 to 30 V/m. They did not appear to be correlated with any of the other measured variables.

The electrical currents induced in the human body by electric and magnetic fields can be compared under some circumstances/4/. However,the distributions of these currents are somewhat different with the magnetic-field induced current being more concentrated near the surface of

the body. Allowing for this difference, the electrical current induced in an ungrounded person (the most likely residential situation) by a magnetic field of 0.22 μT, the 24-hour average field associated with VHCC homes in the W-L code, is the same as the current induced by an electric field of 10 to 20 V/m. Therefore, if it is taken as a hypothesis that biological effects are related to induced currents, electric fields can certainly be a confounding factor.

CONCLUSIONS AND GUIDELINES

Residential daily average magnetic fields in two U.S. survey areas are 1 μT or less (including seasonal variations) except within 1 m or so of appliances and possibly ground-path conductors. Statistically, a 4:1 ratio is observed for 24-hour average fields between the highest and lowest of the Wertheimer-Leeper wire codings. However, due to large variations, predictions for individual houses or small groups of houses will be very uncertain.

Spot measurements display a similar correlation with the wiring codes but may vary over a range in excess of 100:1 with respect to the long-term magnetic field averages. They are therefore unsuitable for ranking individual houses.

The available data show that daily average magnetic fields in homes in the surveyed areas are related to the number of nearby secondary service drops and the number or size of primary phase conductors, indicating that nearby external wiring or at least the general density of this wiring plays a significant role in the production of internal fields. However, they also show that measurements made with the main purpose of compiling statistical data are not very suitable for identifying the operative mechanisms in individual residences.

Several questions remain to be answered. For example: do the same statistical relationships hold in Ontario where wiring and construction practices or electrical usage may differ? Can surrogate methods of predicting long-term residential magnetic-field environments be improved to the point where they are valid for small groups of homes or even individual houses? What mitigation measures would be effective if the residential magnetic-field environment had to be reduced? Do other potential confounding factors need to be assessed as well as magnetic fields?

With respect to the Source Characterization program, which is intended to produce improved predictive models and to identify mitigation methods, these findings confirm the need for measurements to be made in individual residences with sufficient spatial and time resolution to establish mechanisms. In particular, the contribution from ground currents needs to be clearly established and broken down into its constituent parts due to induction from external wiring, common impedance coupling (among several residences), unbalance currents arising from electrical usage within the residence itself, or other factors.

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